Relationships Between Early Acute Pain Scores, Autonomic Nervous System Function, and Injury Severity in Wounded Soldiers

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Background: Acute pain after injury affects the comfort and function of the wounded soldier and the physiology of multiple body systems. In the civilian population, pain alters the function of the autonomic nervous system, causing increased heart rate and blood pressure. However, there are no data regarding the impact of combat-related pain on physiologic responses. This study is a retrospective analysis that examined the relationship of pain and physiologic parameters in injured soldiers.

Methods: After Institutional Review Board approval, the Joint Trauma Theater Registry (JTTR) was queried to identify soldiers who had pain scores recorded in the Emergency Department (ED) in theater. Subject data collected from the JTTR included the following: pain score, Injury Severity Score (ISS), blood pressure, heart rate, and respiratory rate.

Results: We identified 2,646 soldiers with pain scores recorded in the ED. The pain score was not related to most physiologic parameters measured in the ED. Pain intensity had no correlation with blood pressure or heart rate. However, there were relationships between the pain score and respiratory rate, with patients reporting a pain score of 10 having a slightly higher respiratory rate. Increasing pain scores were also associated with increased ISS ($p < 0.001$).

Conclusions: In contrast to data from civilian patients, early pain scores were not related to heart rate or blood pressure. A pain score of 10 corresponded to an increased respiratory rate. Despite little relationship between pain and injury severity in the civilian population, the increasing ISS was proportional to the pain scale in wounded soldiers.

Key Words: Pain score, Combat casualty, ISS, Vital signs.

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Combat casualties arising from the current US military operations in the global war against terror, including Operation Enduring Freedom and Operation Iraqi Freedom, have resulted in the increasing recognition of pain and pain treatment as a problem that must be addressed. Technological improvements in body armor and vehicle design, in combination with advancements in far forward medical care, have greatly increased the survivability of combat injuries that would have proven fatal as recently as the Vietnam War.[1,2] In addition, the types of trauma experienced on the battlefield today, including blast-related injuries from improvised explosive devices (IEDs), land mines, and rocket-propelled grenades, result in complex wounds often affecting multiple physiologic systems and requiring extensive periods of treatment and rehabilitation.[3,4] These injuries are often accompanied by severe pain, which requires aggressive treatment.

Combat injuries can result in severe acute pain, and initial pain control can increase patient comfort and aid in evacuation from the point of injury,[5,6] but achieving adequate pain management for combat casualties presents unique challenges. In an austere environment, such as the battlefield, the immediate priorities must be stabilization of the patient and efficient evacuation. In a combat setting, medics must balance the need for life-saving care with the goal of removing the casualty from further harm. Thus, complete elimination of pain may be impossible until safe removal to a surgical theater, where general anesthesia is available.

Uncontrolled acute pain can lead to serious long-term sequelae, including chronic pain syndromes. Pain after trauma affects not only the comfort and function of the wounded soldier but also the function of multiple physiologic systems. Acute, uncontrolled pain induces a physiologic stress response, affecting the autonomic nervous system.[7] This autonomic nervous system activation results in an increase in sympathetic system activity and a decrease in parasympathetic system activity, leading to increased heart rate, increased blood pressure, and widened bronchial passages.[8,9] These responses are, initially protective, however, the continuation of the stressor and its physiologic effects are maladaptive and can initiate or exacerbate harm to multiple systems. Although efforts to link vital signs to pain severity have largely been unsuccessful, multiple studies have reported correlations between the presence of pain and elevated heart rates, respiratory rates, and blood pressure.[8–11] This

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would indicate that it is any pain, without regard to its severity, that may affect these vital signs. However, there are little data regarding the relationship between combat trauma-related acute pain and autonomic nervous system responses, including heart rate and respiratory rate. One study examined the relationships between heart rate variability and pain in a combat casualty population, but this study was conducted months after injury in a Level II Veteran's Affairs (VA) polytrauma center.[12]

Naturally, one would expect that pain levels should be proportionate to injury severity, with patients reporting severe pain experiencing more severe injuries than a patient reporting mild or moderate pain. However, there is very little in the literature regarding early pain and injury severity levels, especially in polytrauma patients.[13–15] Indeed, most studies have failed to find a correlation between injury severity and pain intensity. However, no study has analyzed these relationships in combat casualties presenting to the Emergency Department (ED) in theater.

This study is a retrospective analysis that examines the relationship of pain and physiologic response in injured soldiers in the ED in theater. In addition, the relationship between pain intensity and injury severity is examined in this study. Understanding the relationships between early acute pain, injury severity, and autonomic nervous system function may provide evidence for improved initial patient evaluation and result in more effective battlefield pain control.

MATERIALS AND METHODS

This study was conducted under a protocol reviewed and approved by the US Army Brooke Army Medical Center Institutional Review Board, and in accordance with the approved protocol. After Institutional Review Board review, the Joint Trauma Theater Registry (JTTR) was queried to identify soldiers who had pain scores recorded in the ED in theater. Only patients who had recorded pain scores on admission to a Level II or III hospital were included. Patients who experienced severe brain injury, as indicated by a total Glasgow Coma Scale (GCS) score of less than nine, were excluded from the study. Of the remaining 2,646 subjects, 9 (0.3%) had GCS scores indicating moderate brain injury (9–12), whereas the remainder had GCS scores of 13 to 15, the vast majority of whom (2,585 subjects; 98%) had the best response score of 15.

None of the patients' records indicated receipt of a nerve block or surgery before admission to the ED. Of the 2,646 subjects included in this study, 412 (16%) received an opioid before arriving to the ED. Of these, 40 received fentanyl and 372 received morphine. These patients were included in the study because statistical analysis of the data showed no difference in conclusions based on their inclusion. On admission to the ED, the subjects were asked to verbally rate their pain intensity using a verbal numeric rating scale of 0 to10. In this scale, a rating of 0 corresponds to no pain and a rating of 10 corresponds to the worst pain imaginable. The JTTR medical records of these subjects who had recorded pain scores were then queried to extract patient vital sign data, including systolic and diastolic blood pressures, heart rate, and respiratory rate. The first vital signs taken in the ED were used in the data analyses. Other data were also collected about these subjects, including Injury Severity Score (ISS). The ISS included in the analysis was determined based on the findings from arrival. The method of its calculation is based on a modification of the Baker ISS.[16] Injuries are given numerical scores based on their severity using an Abbreviated Injury Scale (AIS) score. While the original ISS is the total of the three highest AIS scores from the three most severely injured body regions, the ISS calculated in this study includes the three highest AIS scores without regard to the body region injured.[17] This ensures that the three most severe injuries are included in the score, even if more than one of these injuries is located in the same region.

Statistical analysis was accomplished using the SAS Enterprise Guide version 4.2 software. Data were analyzed using a nonparametric form of an analysis of variance test, the Kruskal-Wallis test. Because 11 groups were compared, pair-wise comparisons were not considered significant until the 0.005 level, before adjustments. A Bonferroni correction for multiple comparisons was used. The independent variable in these analyses was the early pain score. Dependent variables were heart rate, systolic blood pressure, diastolic blood pressure, respiratory rate, and ISS. The null hypotheses were that the dependent variables were not related to the pain score. A p value of <0.005 was considered significant and indicated that the null hypothesis could be rejected.

RESULTS

A total of 2,646 soldiers with pain scores recorded in the ED were identified. Table 1 depicts the distribution of the patients for each pain rating. Of these subjects, 214 (8%) reported a pain score of 0. Mild pain was reported by 362 (14%) of subjects, whereas moderate pain, of between 4 and 6, was reported by 778 (29%) subjects. The largest number of subjects, 1,292 (49%), reported experiencing severe pain

TABLE 1. Two Thousand Six Hundred Forty-Six Soldiers Presented to the ED in Theater With Pain Scores

Pain Score	N	SBP	DBP	Heart Rate
0	214	132.8 ± 16.3	72.6 ± 13.2	82.0 ± 18.5
1	49	133.7 ± 12.2	72.4 ± 10.1	96.7 ± 92.2
2	148	133.5 ± 15.0	70.3 ± 13.0	90.1 ± 75.8
3	165	133.0 ± 14.9	71.5 ± 12.4	83.6 ± 17.2
4	173	132.8 ± 13.3	72.9 ± 12.8	88.3 ± 54.9
5	317	133.5 ± 14.3	73.3 ± 12.1	83.6 ± 16.9
6	288	132.9 ± 16.4	7 ± 37.0	86.1 ± 29.5
7	328	132.3 ± 16.4	74.0 ± 41.1	85.1 ± 18.1
8	373	134.0 ± 17.7	72.6 ± 12.8	87.4 ± 42.9
9	195	135.0 ± 19.4	79.7 ± 70.6	86.0 ± 19.0
10	396	130.7 ± 22.9	73.5 ± 48.2	91.6 ± 21.9

Their injuries were from combat and noncombat injuries. Their pain scores were assessed on a scale of 0–10 verbal Numeric Rating Scale (NRS) with 0 being no pain and 10 being the worst pain imaginable. There was no significant difference in systolic or diastolic blood pressure in the soldiers with various levels of pain. Numbers displayed in column 2, systolic blood pressure (SBP) and column 3, diastolic blood pressure (DBP), represent the mean BP value ± SD. Mean heart rates ± SD are listed in column 4.

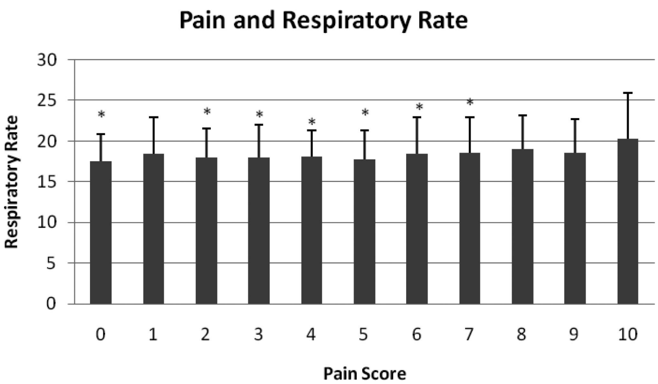

Figure 1. Soldiers with a pain score of 10 have increased respiratory rates. The respiratory rates of soldiers reporting a pain score of 10 are generally significantly higher than those reporting lower pain scores (*$p < 0.001$ and denotes significant difference when compared with a pain score of 10). Error bars represent 1 SD from the mean.

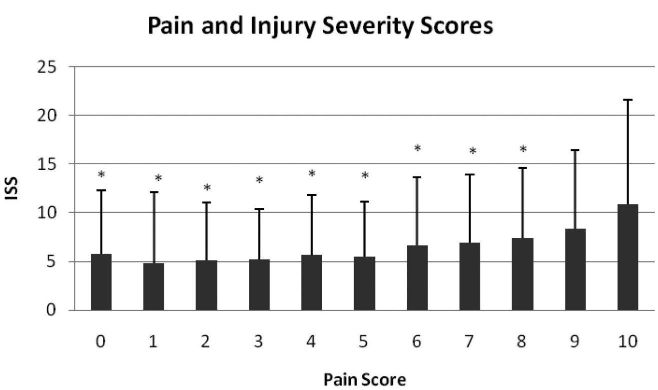

Figure 2. Soldiers with higher pain scores are more severely injured. The ISS increase with pain levels (*$p < 0.001$ and denotes significant difference when compared with a pain score of 10). Error bars represent 1 SD from the mean.

between 7 and 10 on the verbal numeric rating scale, on arrival at the ED. More than 90% of patients presenting to the ED in theater reported experiencing some level of acute pain.

The vital signs of these subjects were then analyzed. All 2,664 subjects had blood pressure data available (Table 1). There was no significant difference in either systolic or diastolic blood pressure in the soldiers with various levels of pain. There was also no significant difference in heart rates between soldiers reporting different pain levels (Table 1). However, there was a small but statistically significant difference in the respiratory rates of soldiers in relation to their reported pain scores. Figure 1 shows that the respiratory rates of soldiers reporting a pain score of 10 were significantly higher than those reporting other pain levels ($p < 0.0001$), with the exception of soldiers reporting pain levels of 1, 8, and 9.

Finally, we examined whether the pain levels were related to the ISS. As shown in Figure 2, there was a positive correlation ($p < 0.0001$) between the self-reported pain score and the ISS. Subjects that were more severely injured reported more intense pain.

Limitations

This is a retrospective study with all the typical limitations of such studies. Retrospective studies rely on existing data recorded for clinical reasons, thus some data that could strengthen the conclusions may not be available. Retrospective chart reviews do not generally allow for establishing causal relationships between variables. In addition, there is inherent variance in the quality of the data collected and the extent of data collection over time. The JTTR has undergone improvements and changes as it has grown, and these changes could give rise to sample bias or discrepancies over time.

To qualify for inclusion in the study, the subject must have been alert and aware enough to report a pain score on arrival to the ED (GCS >8), which resulted in sample bias. The skill level of the initial provider was also not included in our analysis, such as whether the wounded soldier was cared for by a trained combat medic, a physician, or a fellow soldier with little or no medical education. The time between injury and arrival in the ED was not included in the analysis, and such nonstandard time intervals may introduce uncontrolled-for variability in the sample. Other confounders may not have been identified. Finally, the population examined was a military population and thus any conclusions may not apply to civilian trauma care.

DISCUSSION

Similar to the civilian sector, combat injury-related pain is an important component of traumatic injuries and must be treated.[4,14] However, there are a multitude of unique challenges that arise in a far forward medical environment. The severity and complexity of wounds suffered by combat casualties in the current military operations often exceeds that of common injuries treated in hospitals in the United States, with many wounded warriors suffering polytrauma, defined by the Veterans Health Administration as "concurrent injury to two or more body parts or systems resulting in cognitive, physical, psychologic, or other psychosocial impairments."[14]

Logistical considerations also play a large role in determining the feasibility of treatment options in austere environments such as the battlefield. The weight, size, availability, and stability of equipment and supplies are of significant concern.[18] In addition, wounded soldiers often endure prolonged evacuation times over difficult terrain and/or great distance, which can result in delayed onset of definitive medical care and effective pain treatment.[5] Other special circumstances that effect medical care in a theater of war include the need to ensure safety of the wounded soldier and the medical providers. The process of evacuation itself can be risky, because it may expose soldiers to enemy fire or IEDs. Other concerns in a far forward environment include the presence of a limited number of highly trained medical professionals, including doctors and nurses.[19–21]

The effects of acute pain on autonomic nervous system function, including its affects on physiologic parameters such as heart rate, blood pressure, and respiratory rate, have been used in the civilian population as nonbiased indicators of the presence of pain.[8,11] These outputs do not rely on patient self-reporting or a patient's cognitive or verbal abilities. Although researchers have been largely unable to correlate the intensity of pain with these vital signs, it is clear that the presence of pain is generally accompanied by increased heart rate, blood pressure, and respiratory rate in civilians suffering from pain of various etiologies.[22] This study is the first to examine a relationship in combat casualties between early pain scores in the ED in theater and heart rate, blood pressure, respiratory rates, and ISS.

In contrast to data from civilian patients, we found that the pain score was not related to most physiologic parameters measured in the ED. Pain intensity had no correlation with systolic or diastolic blood pressure. Pain scores also did not correlate with increased heart rate. We did identify that respiratory rates in patients reporting a pain level of 10 were slightly higher than in patients reporting other pain levels. However, despite the statistical significance of the different respiratory rates, it is unlikely that such a small increase would be useful in a diagnostic or treatment scenario and is likely due to unidentified confounders.

Although it seems intuitive that patients who are more severely injured would experience more pain, studies investigating this have thus far been overwhelmingly negative.[23] In the civilian population, it seems that there is no relationship between how severely wounded a patient is and the level of pain they report experiencing.[24] However, we found that despite little if any relationship between pain and injury severity in the civilian population, the ISS was proportional to the pain scale in wounded soldiers; however, ISS was not an appropriate independent predictor of pain levels.

The differences this study identifies between published data on the civilian population and the combat-wounded population could be due to a multitude of factors. There are many competing stimuli that might be present in combat casualties that may be different from those experienced by civilians, including hemorrhage, trauma, injury characteristics, and analgesic use. Generally, the only analgesic option available to the combat medic on the battlefield is 10 mg intramuscular morphine; combat casualties must wait until arriving at the ED for additional analgesia, and the time for transport to the ED can vary.[5] Situational factors may also inform these differences between the civilian and combat-wounded populations. Perhaps, the autonomic nervous system activation that occurs in civilians as a consequence of pain has already occurred in the combat casualties before their injuries due to environmental stimuli on the battlefield, and thus response to pain may be masked or exhausted. Finally, demographic characteristics of the populations themselves may contribute to their apparently contrasting physiologic response to pain or effects of injury severity on pain. Unlike civilian pain patients, combat casualties are overwhelmingly young, fit males.[1] Perhaps, if civilian studies were conducted in this narrow cohort, the findings may be similar to the findings of this study. Future studies will be conducted to determine the validity of the conclusions of this study and to further improve pain control and treatment of our combat casualties.

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